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TRANSLATION

ENGLISH TITLE: Effect of Damping the Detonation Under the Action of a Magnetic Field Arising During the Explosion of Charges in Casings

FOREIGN TITLE: Effekt Zatukhaniya Detonatisii Pod Deystviyem Magnitnogo Polya, Voznikayushchego Pri Vzryve Zaryadov vv v Obolochkakh

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ABSTRACT: The damping process of explosion in tubes was considered as behavior of a "cold plasma" in a magnetic field. From theoretical considerations and experimental data, an explosive charge acted on the explosion as a generator and electromagnetic oscillations in a broad frequency range including very high frequencies. The electromagnetic field arising in the tube affects the process in the reaction zone and is the main factor causing the damping of detonation.

KEY WORDS: Plasma Physics, Detonation Kinetics, Detonation Shock Wave, Magnetic Field, Explosive Charge, Shock Tube, Plasma R and D

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Studies of the channel effect [3, 4, 5] have allowed us to accumulate a great deal of experimental material and to make a number of interesting conclusions concerning the influence of the changes of individual factors on the length of the detonated portion of a charge. However, the reasons for damping of detonation of charges in tubes remain unclear.

The hydrodynamic theory of damping of detonation, based on the assumption of a decrease in the limiting diameter of a charge below the critical diameter under the influence of shockwaves, which catch up to the detonation wave and change the density of the explosive, has not been confirmed by experimental results, and at times has even been contradicted by them. The glow in the gap between the explosive charge and walls of a tube, which may occur as a result of bremsstrahlung of charged particles arising in the zone of the explosive reaction, the influence of the cross section of the gap, which can be looked upon a waveguide, and the shell material, the determining factor for which is not the mechanical strength or density, but rather the electrical conductivity (for steel, aluminum and brass) or dielectric properties (for glass, polyethylene and plexiglass), the influence of explosive composition, particularly the content of easily ionized elements (alkali metals, aluminum) and the initial impulse, roughness of the tube and presence of apertures in tubes and other factors indicate that there is some other reason for the damping of the detonation of elongated charges when exploded in boreholes, pipes and various types of shells.

In our opinion, the main factor resulting in the damping of detonation is the magnetic intensity of the electromagnetic field arising in the process of expansion of explosion products. It has been experimentally established that in a constant magnetic field, the detonation velocity of an explosive decreases if the direction of detonation and intensity of the magnetic field coincide. The effect of damping of a detonation in a magnetic field can be explained if the material is in the "cold plasma" state in the reaction zone adjacent to the leading edge of the detonation wave, the length of which for certain explosives fluctuates from a fraction of a millimeter (nitroglycerin)

to several centimeters (ammonite). Thus, it seems possible to look upon the damping process as the behavior of a "cold plasma" in a magnetic field.

The behavior of plasmas in homogeneous and heterogeneous fields (magnetic traps) has been studied quite completely with the exception of a few peculiarities. In a strong magnetic field, the electrons and ions cannot move freely in the direction perpendicular to the lines of force. Under the influence of the Lorentz force, the trajectory of each charged particle winds in a spiral around a line of force. The Larmor radius r of curvature of this spiral in a homogeneous magnetic field with intensity H is inversely proportional to the intensity:

$$r \approx \frac{1}{H}. \qquad (1)$$

In the case of motion of a particle in a zone with changing intensity, we have

$$r \approx \frac{1}{\sqrt{H}}. \qquad (2)$$

With increasing intensity H, the Larmor radius decreases, the number of collisions increase, which is equivalent to increasing the pressure.

The influence of a magnetic field on a plasma is not limited to a change in the trajectories of charged particles and an increase in the number of collisions. The diffusion factor changes, diamagnetic properties, oscillations and waves appear.

In the case in question, the motion of the zone of explosive reaction ("cold plasma") in a magnetic field with an intensity of tens of thousands of oersteds and the increase in the pressure in this zone cause damping of the detonation, since it is known that when pressure increases the detonation rate decreases [1]. Consequently, if the direction of detonation and intensity are parallel, the length of the detonation damping path 1 in the magnetic field is proportional to the pressure increment Δp or the Larmor radius r, and for a heterogeneous field we have

$$l \approx \frac{1}{\sqrt{H}} \ [\text{см}]. \qquad (3)$$

Thus, using magnetic hydrodynamics (not hydrodynamics) we can explain the damping effect of the detonation of elongated charges in a strong external magnetic field.

Naturally, the damping of detonation resulting from the explosion of elongated explosive charges in the magnetic field of the earth can be observed

only with very long charges, located along the lines of magnetic force, due to the low intensity of this field. Actually, when explosive charges are set off in pipes, boreholes and thin shells, magnetic fields can be observed of significantly higher intensity than the terrestrial field. The formation of these fields can be explained only by relating them to the process of development of the explosion itself.

In 1939, A. G. Ivanov first detected electromagnetic oscillations during explosion of explosive charges. G. I. Pokrovskiy presents interesting data in several works concerning the appearance of an electrical potential on barriers and antennas during the explosion of ordinary and shaped explosive charges. He first set forth the hypothesis that the source of the radio oscillations consists of the expanding ionized explosion products. Research which we have performed (at MakNII) and abroad has confirmed the hypothesis of G. I. Pokrovskiy of the development of oscillations at the moment of expansion of the explosion products.

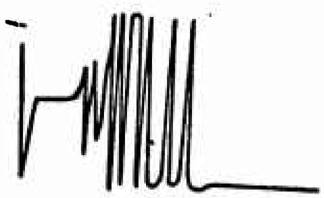

Figure 1. Oscillogram of emf Induced in Magnetic Probe Placed in a Charge.

These initial ideas allowed us to perform theoretical and experimental studies of the electromagnetic fields produced by explosion of open charges and charges in tubes, boreholes and thin shells in 1967. When charges weighing from several grams to 10 kg were exploded, SHF electromagnetic oscillations were recorded with wavelengths of 3-4 cm. The electromagnetic field arising around an open explosive charge when it is set off is dissipated into the surrounding space and its effect on the process of further detonation is slight.

We observe a different picture when elongated explosive charges are set off in shells, when there is a free space between the charge and the walls of the shell. The gap between the charge and shell walls plays a dual role: first of all, it allows free expansion of the explosion products, the electron and ion temperatures of which are highest at the initial moment (supporting the most powerful radiation of electromagnetic oscillations in the SHF band); secondly, it creates the possibility of concentration of energy and its channeling, i.e., acts as a waveguide. The electromagnetic field which arises surrounds the zone of the explosive reaction ("cold plasma") and the detonation is damped when this variable and heterogeneous magnetic field acts upon it. The field was recorded using a magnetic probe placed in the gap between the charge shell and explosive charge (Figure 1). The electromagnetic waves excited in the waveguides can be differentiated into two large groups: transverse electric (TE or H) and transverse magnetic (TH and E).

We were primarily interested by the type H (TE) waves, the H vector of which has both a transverse component and a longitudinal component, i.e., the components of the magnetic field parallel to the direction of propagation of the detonation. Only in this case does the magnetic field lead to damping of detonation.

The magnetic field of the wave $(H_z)_{mn}$, with otherwise equivalent conditions, is inversely proportional to the square of the wavelength:

$$(H_z)_{mn} \approx \frac{1}{(\lambda^2)_{mn}}. \quad (4)$$

where m and n are the numbers of half waves laid out correspondingly along the wide and narrow walls of the waveguide.

For each type of wave, there is a certain limiting wavelength λ_0 in waveguides of various cross sections, "preventing" propagation in the waveguide of longer waves than the critical length.

When elongated charges are exploded in shells, if only the size of the gap (waveguide) is changed, with unchanged density, type of explosive and charge radius, the attentuation path length is proportional to λ_0.

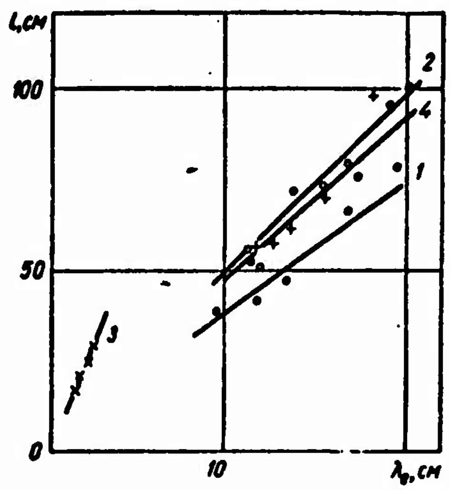

Figure 2. Experimental Dependences of Lengths of Detonation Path During Explosion of Charges in Shells on Wavelength: 1 and 2, explosion of charge of VP-3 with density 1.2 g/ml with charge radius 0.5 and 0.75 cm respectively in glass tubes; 3, explosion of TNT charge with density 0.5 g/ml and charge radius 1.0 cm in plexiglass waveguide; 4, explosion of PZhV-20 charge, density 1.1 g/ml, charge radius 0.8 cm in glass tubes.

Figure 2 shows the dependence of detonation damping path length on criticial wavelengths in a waveguide. Data on damping path length are taken from experimental works [3, 5]. In all cases, the path length is proportional to λ_0, confirming the theoretical calculations performed above.

Thus, the magentohydrodynamic theory of damping of the detonation of long explosive charges in shells under the influence of the internal magnetic field of the explosion which we have suggested has been theoretically and experimentally confirmed. This allows us to explain the influence of roughness, electrical and dielectric properties of shells, the magnitude of the initial impulse, etc.

The experimental and theoretical studies of the influence of electromagnetic fields produced during an explosion on the process of detonation of an explosive charge which we have presented allow us to draw the following main conclusions: an explosive charge, when exploded, is a generator of electromagnetic oscillations over a broad frequency range, including super high frequencies; the explosion of an explosive charge in a shell with a gap represents generation of electromagnetic energy in the waveguide; the electromagnetic field arising in a waveguide when an explosive charge is exploded influences the process in the reaction zone and is the basic factor causing damping of detonation.

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